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DISTRIBUTION OF TOTAL AND DIFFUSE SOLAR RADIATION AT LAHORE, PAKISTAN

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Abstract: In this research work the solar radiation for Lahore (Latitude31.56)has been studied for efficient utilization of solar energy employing sunshine hour data. The results obtained exhibit the variation of direct and diffuse radiation at Lahore. The diffuse radiation is maximum in the month of July and minimum during the month of April, May and June. The K_t Value indicates the clear sky during the month of January, February, April, May and September to December. Where as during the month of Jun to August the sky is mostly cloudy which is the monsoon months. From the estimated results it is found that with the exception of monsoon months solar energy can be utilized very efficiently through out the year.

Key Words: Diffuse Radiation, Lahore, Solar Radiation, Sky Condition.

Introduction

At present Pakistan is facing serious energy problem due to increase demand of energy, high cost of energy import and high population growth. The rural sector which comprises seventy percent of population is dependent on the use of none commercial energy resources. To overcome this problem one has to develop alternate energy resources. Widely used renewable resources are solar and wind energy which has shown prospects and potential for efficient utilization.

Detail information about the availability of solar radiation on horizontal surfaces is essential for the optimum design and study of solar energy conversion system. The commercial and efficient application of solar energy seems inevitable because of abundant sunshine available throughout the year. Solar radiation data are available for most part of the world but is not available for many countries which can not afford the measuring instrument and technique involved. Global solar radiations are available in Pakistan but diffuse solar radiation are not measured experimentally in any meteorological station of the country. Therefore it is rather important to develop methods to estimate the global and diffuse solar radiation using climatological parameters. Several empirical formula have been developed to calculate the global solar radiation using various parameters. These parameters are Sunshine hours (1) the relative humidity and sunshine hour (2), the declination angle and altitude(3).etc.

Besides these many other workers have reported the estimation of global and diffuse solar radiation employing various climatological parameters. (4). In the present work the solar radiation have been done for Lahore using sunshine data to utilize solar energy.

The Lahore city has an area of 461 acres. It is located at latitude 31.56 N and longitude 74.36 east. It is the capital of Punjab province having a population of

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65 million people.

This work will help the energy strategist and planners to utilize the solar energy potential to solve the energy crises of the province.

Methods of prediction

In the present work the H/H_O, the monthly global solar radiation falling on a horizontal surface at particular location and the monthly mean daily radiation on horizontal surface in the absence of atmosphere is given by the following expression.(4,5)

$$H/H_0 = a + b(n/N) \quad (1)$$

Where n is the monthly mean daily no. of sunshine hour and N is the day length at particular location and "a" and "b" are the climatological determined regression constant. n/N is also called the possible percentage of sunshine hour.

The regression constant "a" and "b" have been obtained from the relationship given as (6) and also confirmed by Frere et.al method (Fere et.al 1980) as given below.

$$a = -0.110+0.235 \cos\Phi +0.323(n/N) \quad (2)$$
$$b=1.449-0.553 \cos\Phi -0.694(n/N) \quad (3)$$

The value H_0 may be determined by the following experession.

$$H_0=24/\Pi\ I_{SC}\ ([1+0.033 \cos (360n/365)]\ [\cos\Phi \cos\delta \sin w_s +2\pi ws\ /360 \sin\Phi \sin\delta] \quad (4)$$

Where I_{SC} is the solar constant, Φ is the latitude of the area, δ is the solar declination and ws is the sunset hour angle.

$$d = 23.45 \sin[360*248+n/365] \quad (5)$$
$$\text{Cos } w_S = -\tan\Phi \tan\delta \quad (6)$$

Prediction of diffuse solar radiation

The diffuse solar radiation H_d can be estimated by an empirical formula which co-relates the diffuse solar radiation component H_d to the daily total radiation H . The co-relation equqtion which is widely used are given below.(7,8)

$H_d /H =1.00-1.13K_T$ (Page,Jk 1964) (7)

$H_d /H =1.390-4.027K_T + 5.53(K_T)\ 2-3.108(KT)^3$ (Liu & Jorden) (8)

Where H_d is the monthly mean of daily diffuse solar radiation and $K_T = H/H_O$ is the clearness index.

Results and Discussion

The input parameters for the estimation of monthly average daily global solar radiation at Lahore, Pakistan are shown in table:1

From table1. it is observed that sunshine duration of Lahore is between 60 to 80% through out the year. Employing these parameters the regression constant 'a' and 'b' are evaluated. Inserting these values in equations (1) the monthly average daily global solar radiation H is estimated. The value of Ho , H , H_b and D for Lahore is shown in Figure (1). Table 2 gives the calculated values for Ho, H , K_t and H_d for Lahore. It also shows the ratio. D/H and D/Ho. It indicates that the value of diffuse radiation to extraterrestrial radiation is not more than 16% with the exception of July which is 19%.

Diffuse solar radiation

The diffuse solar radiation for Lahore is estimated by Liu and Jorden, Page method, as no station in Pakistan measures Diffuse solar radiation. From the estimated result it is seen that contribution of diffuse solar radiation is very low throughout the year with the exception of monsoon months, i,e from Jun to August. The Liu & Jorden method predicts lower values then the Page co-relation. The contribution of diffuse

radiation is blow 35%.(9,10)

The availability of direct radiation is therefore encouraging from utilization point of view. The transmission of D/H_O is between 14 and 19 percent where as of D/H is between20 and 33 percent which means that presence of cloud is only in January and July and mostly the sky is clear which is very favorable condition for solar energy utilization.

Fig: (1) represents a plot of monthly variation of Extraterrestrial, total, direct and diffuse solar radiation at Lahore, Pakistan. In case of direct radiation a dip is seen in the month of July for Lahore. The transmission through atmosphere K_T along with the percent of diffuse radiation is shown in Fig(3). The sky is fairly clear throughout the year except for the month of July.

Sky Condition at Lahore

The transparency of the atmosphere is indicated by fraction of Extraterrestrial radiation that reaches the earth surface as global solar radiation. It is the measure of the degree of the clearness of the sky which is given as below.

$$K_T = H / H_O \qquad (9)$$

Where K_T is the clearness index. H is the global solar radiation and Ho the Extraterrestrial insulation. As shown in figure (3) the sky at Lahore is very clear throughout the year with exception of July.

Statistical Distribution

Statistical distribution of global solar radiation indicates that availability of global solar radiation at Lahore is 65% during the month of May- June and 68% during the month of September to December. In the monsoon period it is 60%

Statistical Distribution of Global Solar Radiation

January - April	61%
May - June	65%
July - August	60%
September - December	68%

Variation of Direct and Diffuse Solar Radiation

There is a large variation in the intensities of direct and diffuse solar radiation due to cloud. This has been indicated in fig(2). The result indicates that during the months of April to June are quit appreciable. The percentage of diffuse radiation contribution to global is low in the month of July. The presence of direct radiation for the month of April, May June will be very useful for utilizing it for solar concentrater ,solar cookers and solar furnaces. The Angstrom model for the determination of the global solar radiation and Liu and Jordan model for the estimation of diffuse solar radiation exhibit the validity of estimation for the location under study.

Conclusion

The result obtained indicates that the solar energy utilization has bright prospects in Lahore, Pakistan. The estimated values of global and diffuse radiation reveals that solar radiation can be very efficiently used to compensate for the energy deficits. For the estimation of diffuse radiation lieu and Jordan and page methods are in good agreement. The experimental data of global and diffuse solar radiation is not available for Lahore, Pakistan ,so estimation has to be done employing sunshine hour of the location.

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Table:1

Input parameter for estimation of monthly Global Solar radiation at Lahore, Pakistan.

Months	Monthly sunshine hours n	Monthly average day length N	n/N percentage of possible sunshine hour
January	5.8	10.2	0.56
February	6.9	10.9	0.63
March	7.3	11.8	0.62
April	9.5	12.7	0.75
May	9.6	13.6	0.70
June	9.3	13.9	0.67
July	7.9	13.8	0.57
August	8.2	13.1	0.63
September	7.7	12.2	0.63
October	8.7	11.2	0.78
November	8.2	10.4	0.78
December	7.7	10.0	0.77

Table 2:
Calculated Solar radiation data for Lahore

Months	Ho mJm^2d	H	KT=H/Ho	H_d/H LJ	H_d/H page	H_d Page mJm^2d	H_d LJ	D= H_d+H_d	D/H	D/Ho
January	20.5	12.0	0.59	0.33	0.33	3.96	3.96	3.96	0.33	0.19
February	25.1	15.8	0.63	0.23	0.28	4.42	3.63	4.02	0.25	0.16
March	30.1	18.6	0.62	0.25	0.29	5.4	4.65	5.03	0.27	0.17
April	36.0	24.5	0.68	0.23	0.23	5.67	5.64	5.7	0.23	0.16
May	39.5	26.1	0.66	0.24	0.25	6.52	6.30	6.4	0.25	0.16
June	41.8	26.7	0.64	0.26	0.27	7.20	6.84	7.0	0.26	0.16
July	40.0	23.6	0.59	0.33	0.33	7.78	7.78	7.78	0.33	0.19
August	37.3	23.1	0.62	0.25	0.29	6.69	5.78	6.24	0.27	0.16
September	32.0	20.2	0.63	0.23	0.28	5.65	4.65	5.20	0.26	0.16
October	26.4	18.5	0.70	0.22	0.21	3.88	4.07	3.97	0.21	0.15
November	21.7	15.4	0.71	0.20	0.20	3.08	3.08	3.08	0.20	0.14
December	19.1	14.5	0.70	0.22	0.21	3.04	3.19	3.12	0.22	0.16

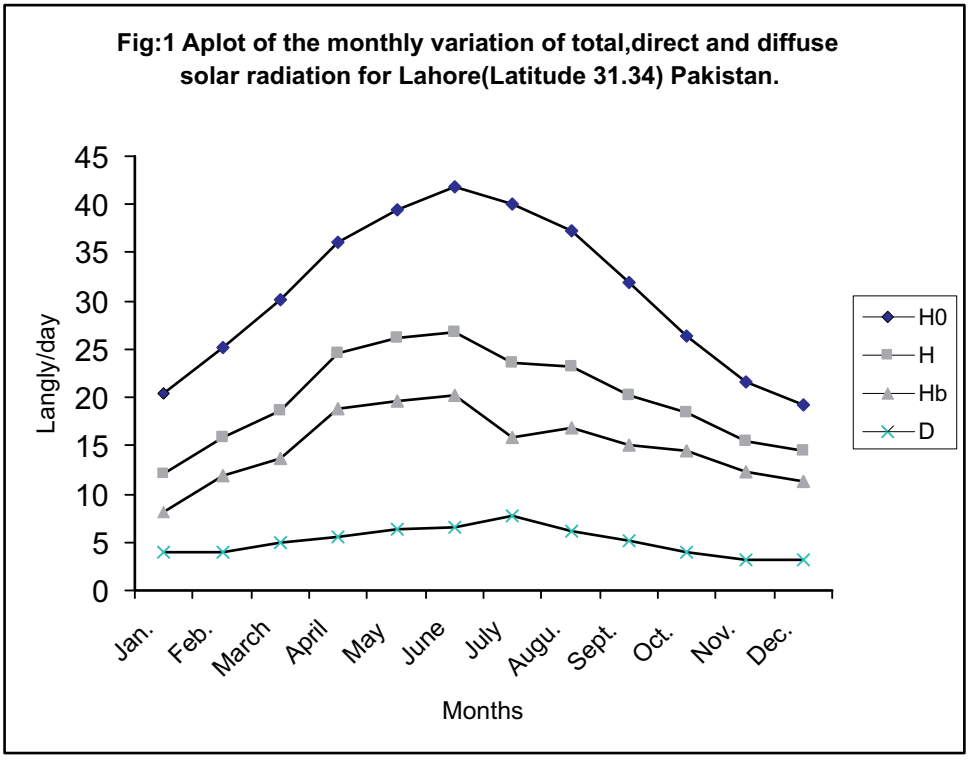

Fig:2 Shows the variation of direct and diffuse radiation for Lahore, Pakistan

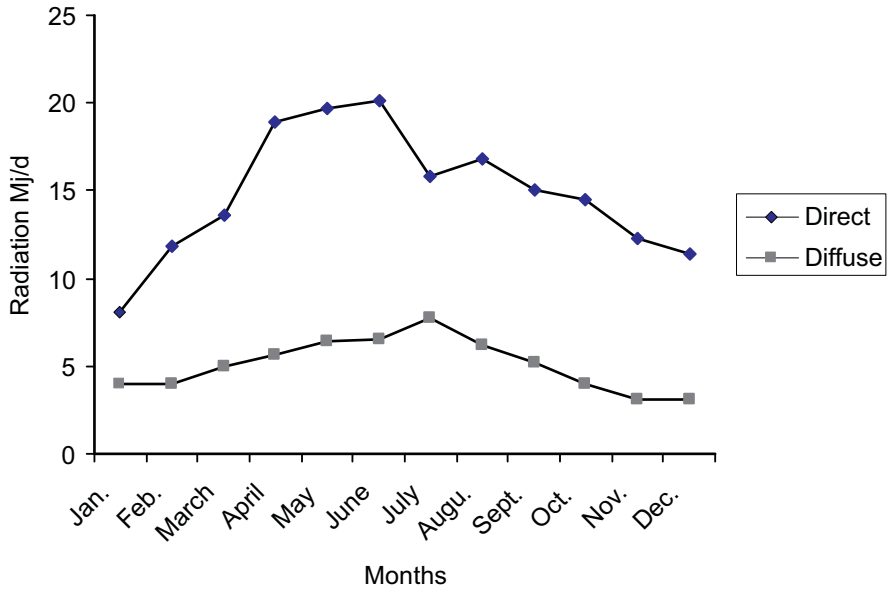

Fig:3 Behaviour of the cloudness index Kt,D/H and D/H0 during a year for Lahore, Pakistan.